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Huang

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(54) **WIRELESS COMMUNICATION DEVICE AND FEED-IN METHOD THEREOF**

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(51) **Int. Cl.**

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H04B 7/02	(2006.01)
H01Q 13/10	(2006.01)
H01Q 5/335	(2015.01)
H01Q 5/35	(2015.01)
H01Q 5/50	(2015.01)

(52) **U.S. Cl.**

CPC ***H01Q 13/10*** (2013.01); ***H01Q 5/335*** (2015.01); ***H01Q 5/35*** (2015.01); ***H01Q 5/50*** (2015.01)

(58) **Field of Classification Search**

USPC 370/297; 343/702, 895

See application file for complete search history.

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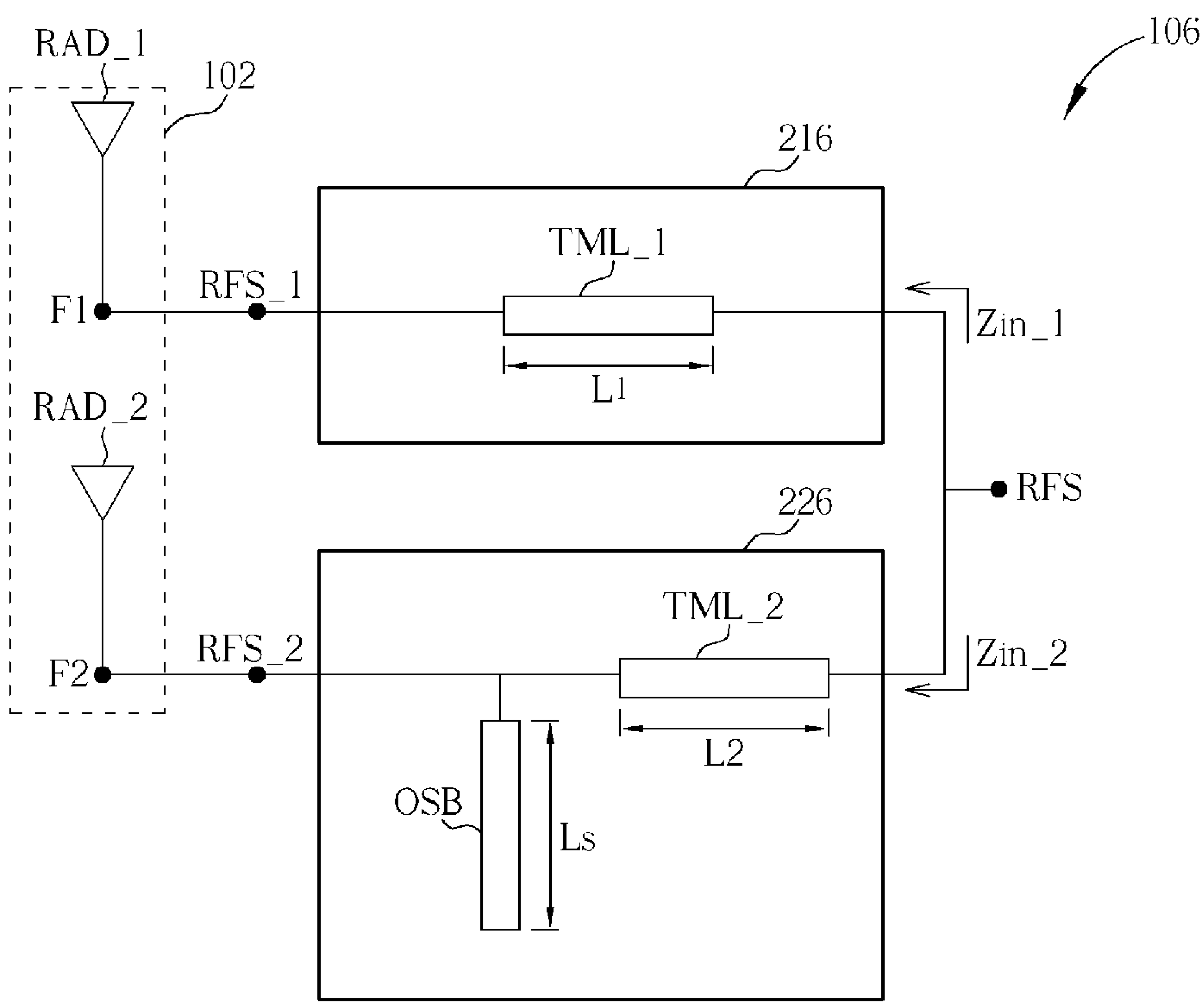
(57) **ABSTRACT**

The present invention discloses a wireless communication device including a slot antenna, a radio-frequency (RF) signal processing module for processing an RF signal transmitted or received by the slot antenna, and an RF signal diplexer coupled between the slot antenna and the RF signal processing module for splitting up the RF signal into a first frequency component and a second frequency component during transmission, and synthesizing the RF signal corresponding to the first frequency component and the second frequency component during reception.

12 Claims, 7 Drawing Sheets



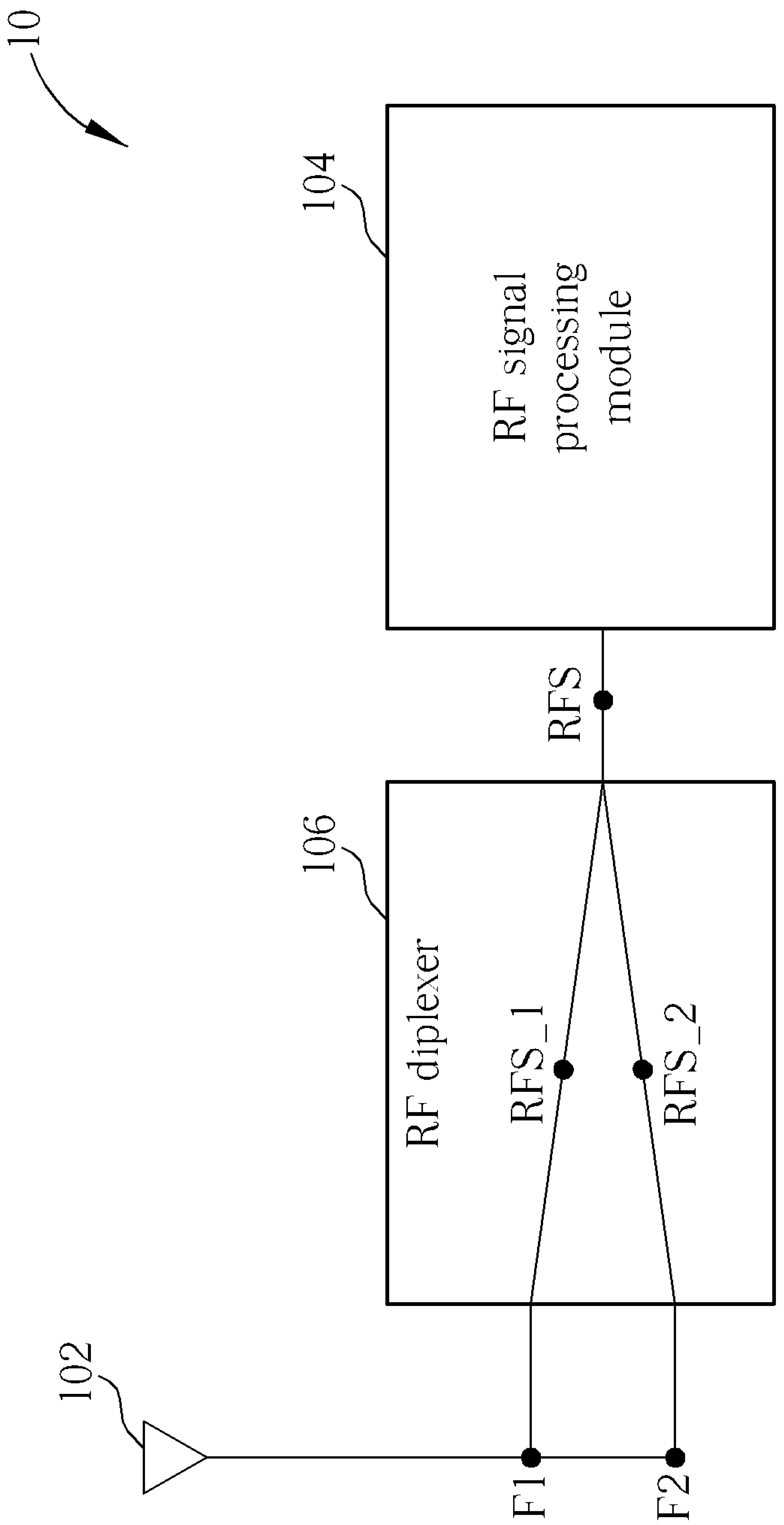

10
104
RF signal processing module
RFS
106
RF diplexer
RFS_1
RFS_2
102
F1
F2

FIG. 1

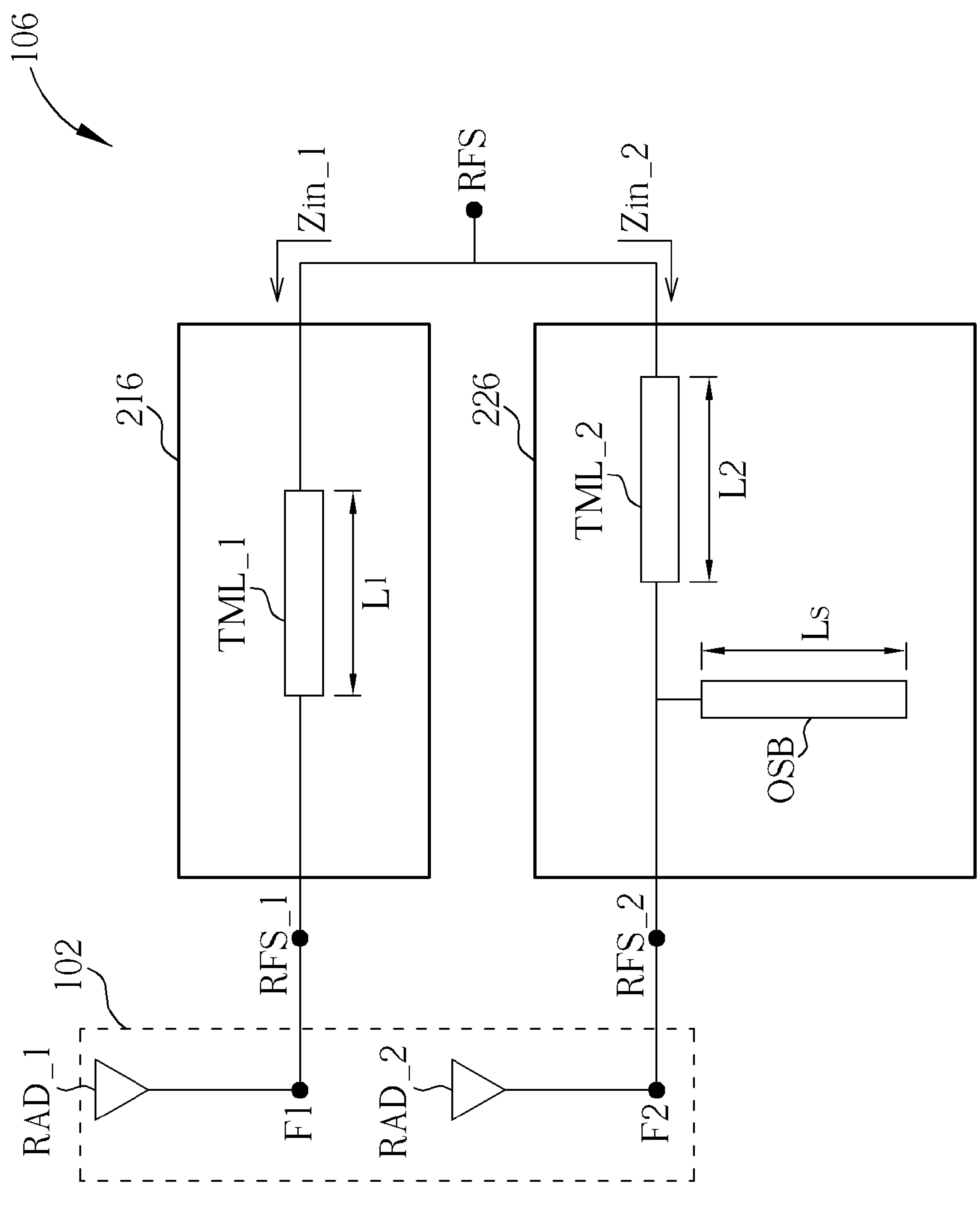

106
RFS
Zin_1
Zin_2
216
226
TML_1
TML_2
L1
L2
Ls
OSB
RFS_1
RFS_2
102
RAD_1
RAD_2
F1
F2

FIG. 2

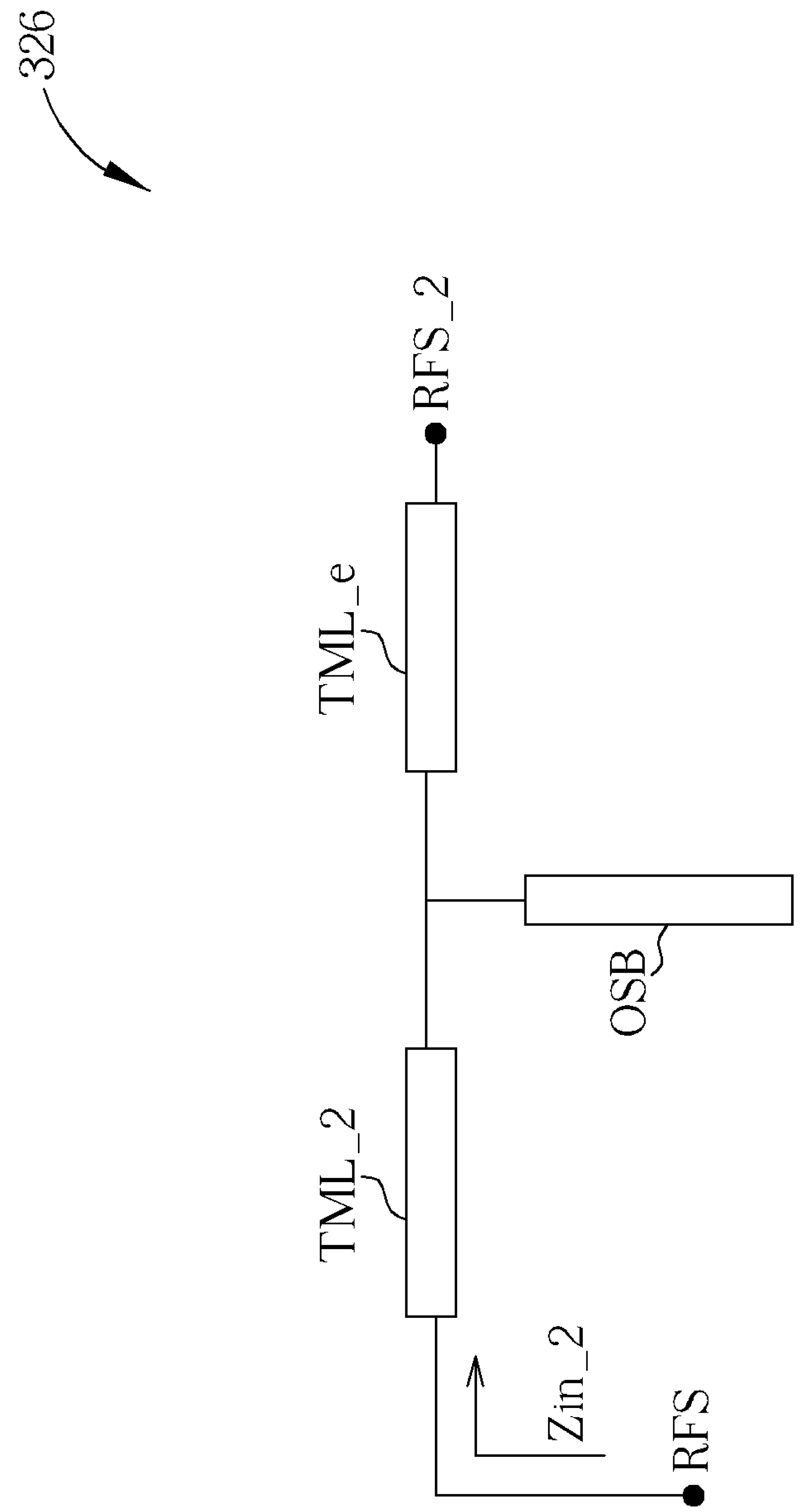


FIG. 3

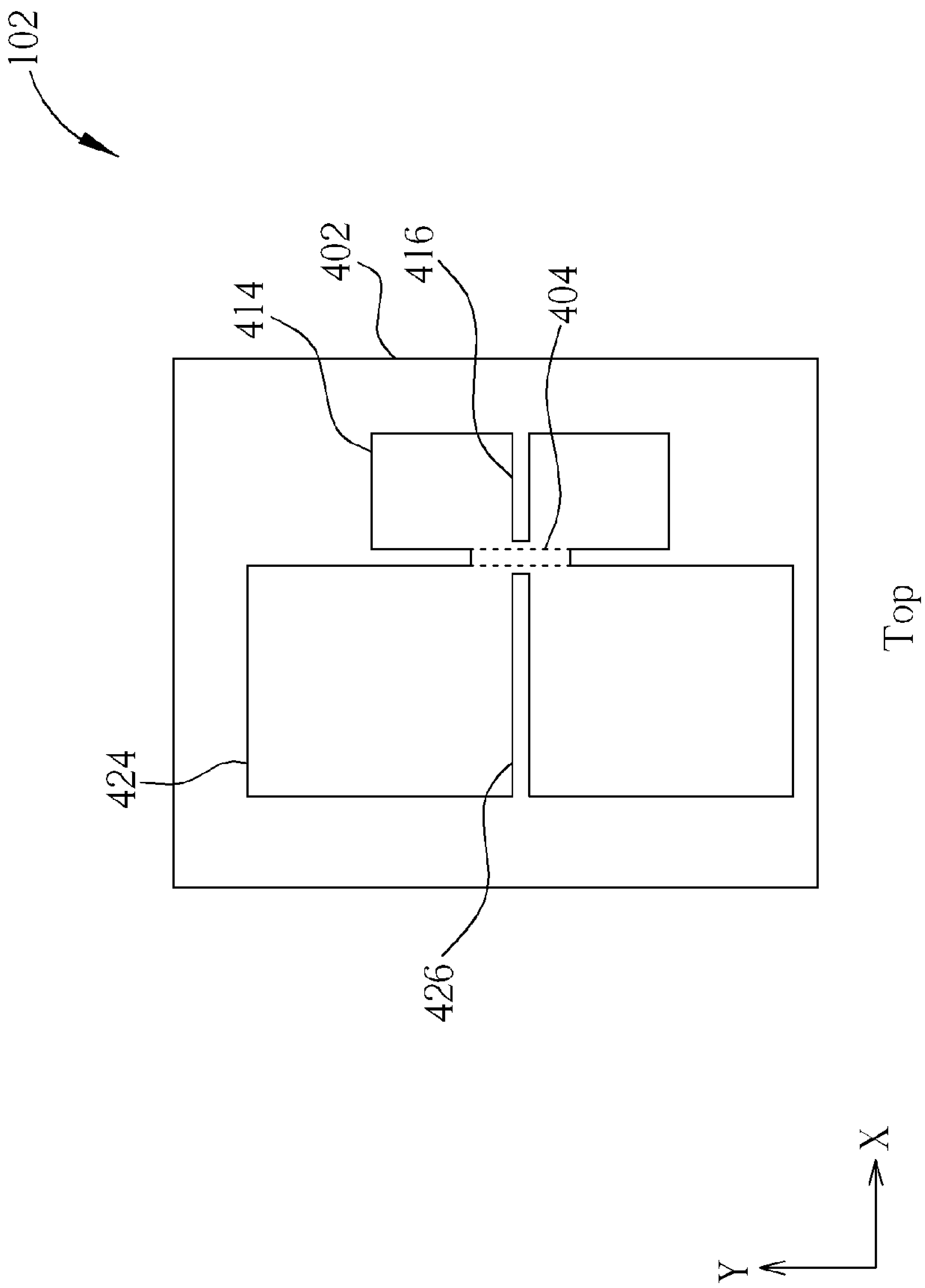


FIG. 4A

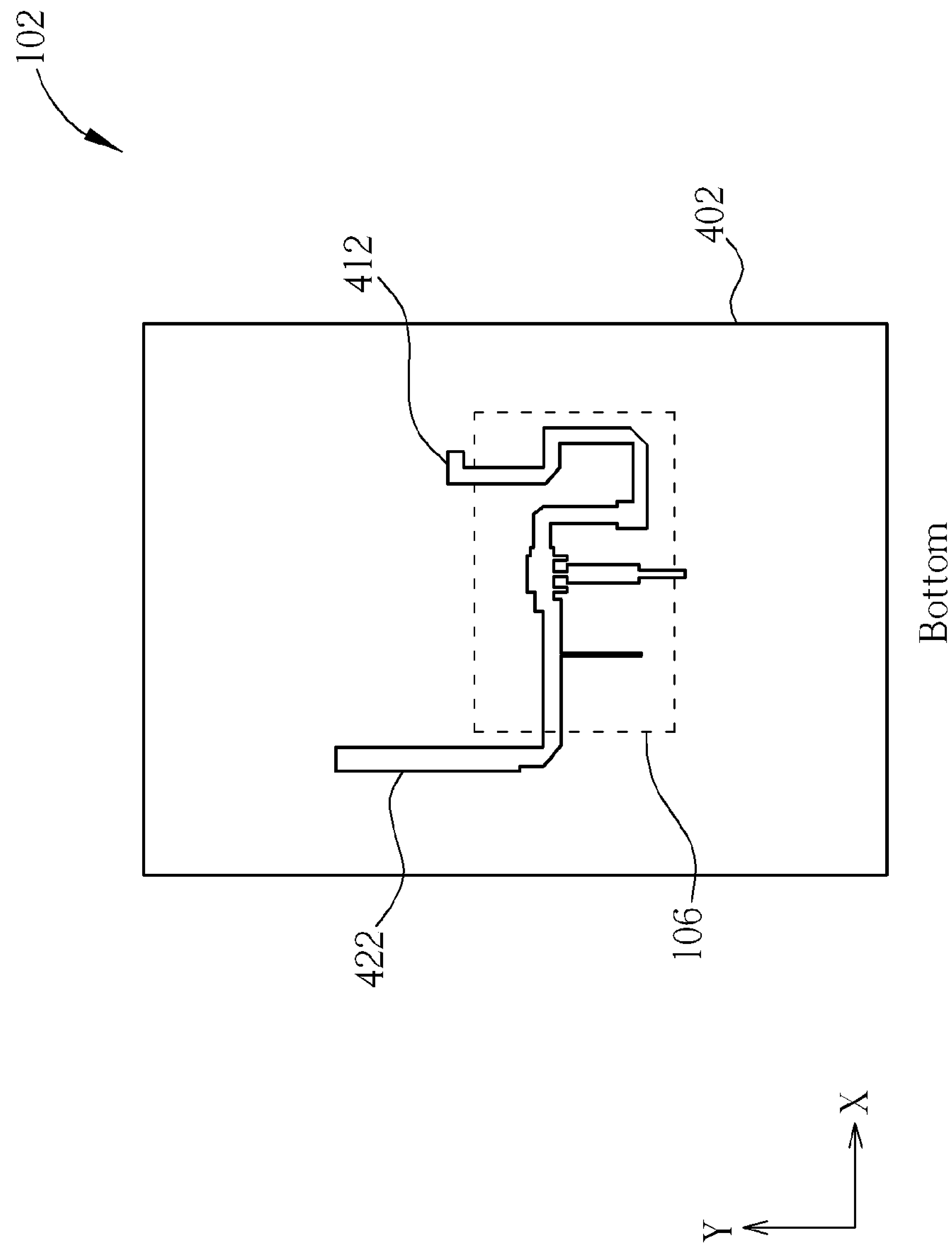


FIG. 4B

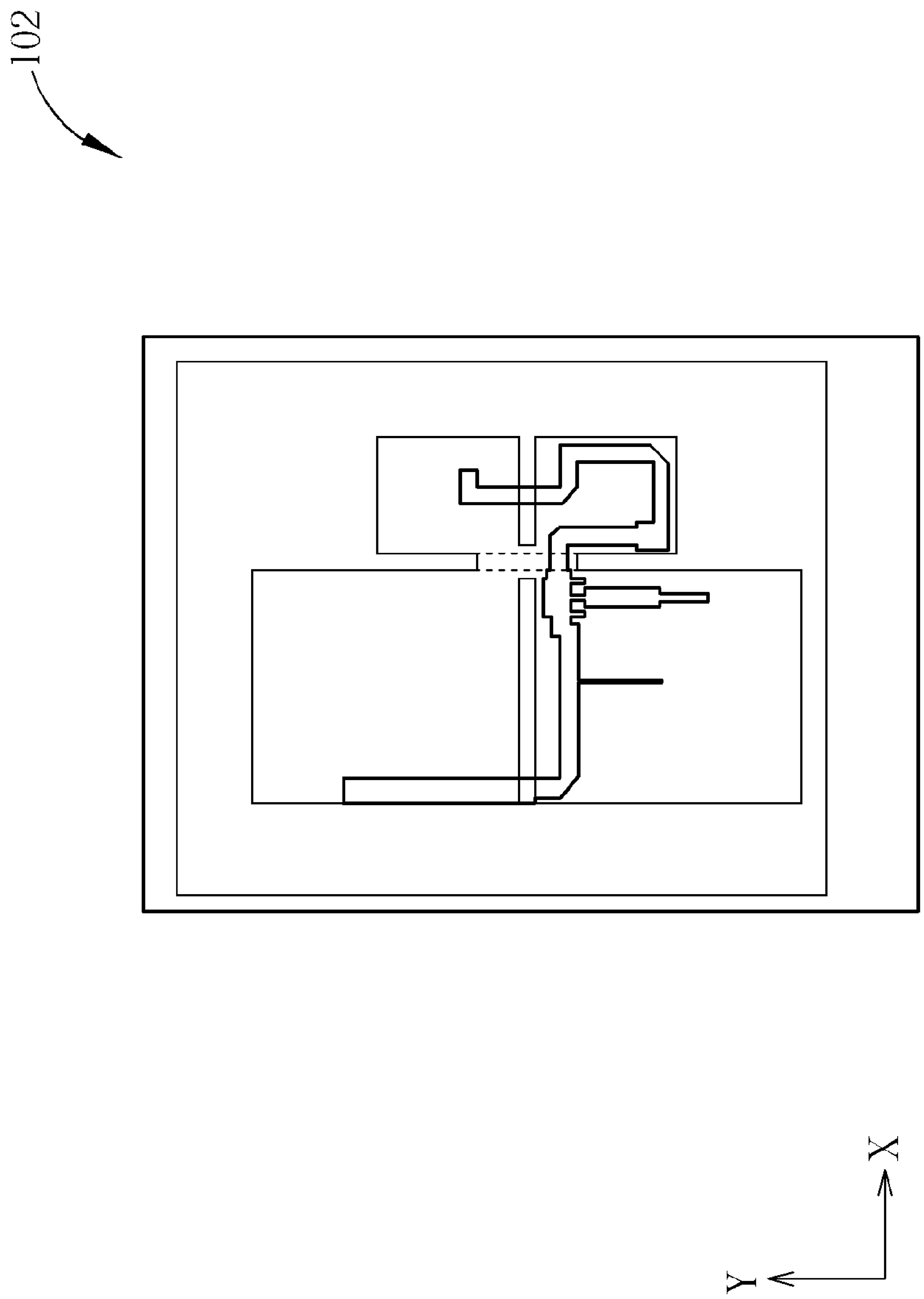


FIG. 4C

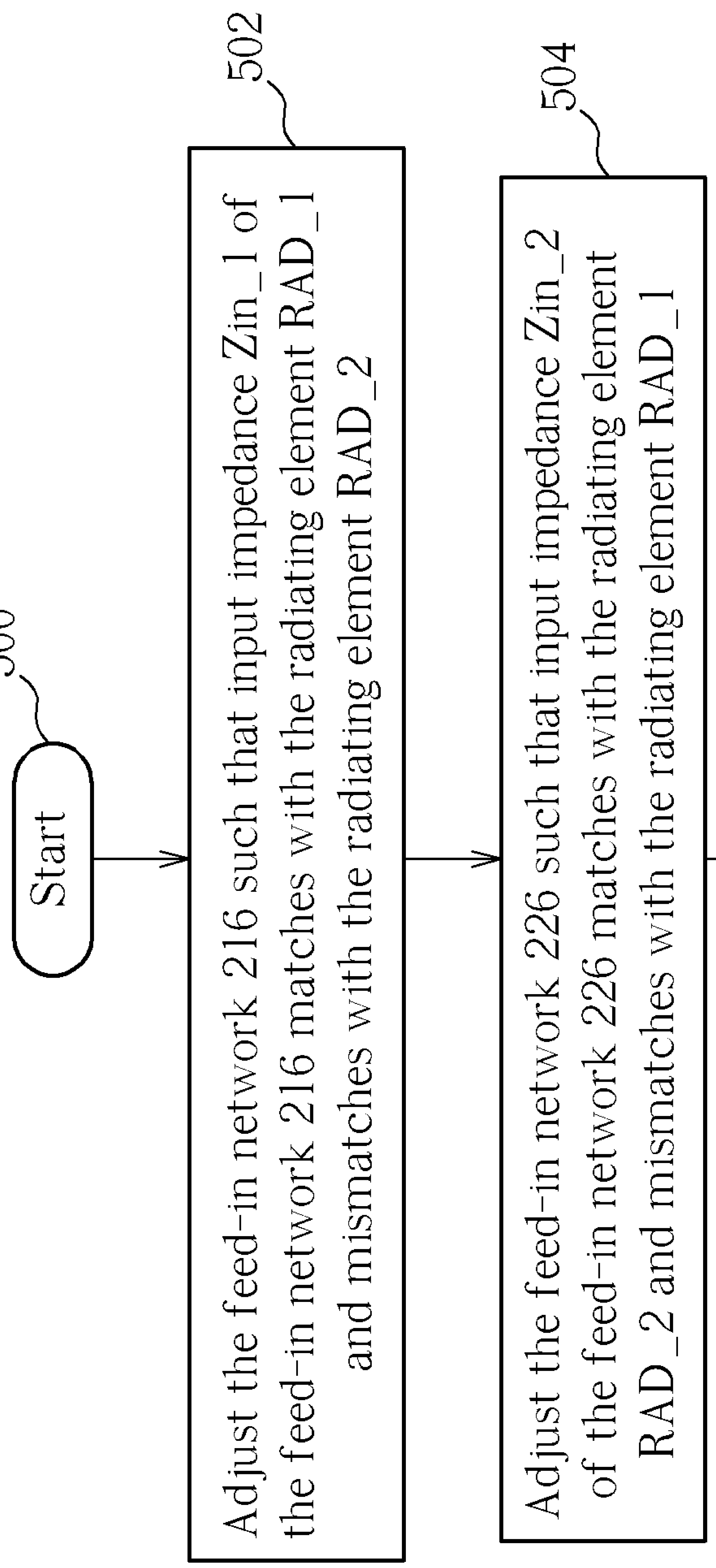

500
Start
502
Adjust the feed-in network 216 such that input impedance Zin_1 of the feed-in network 216 matches with the radiating element RAD_1 and mismatches with the radiating element RAD_2
504
Adjust the feed-in network 226 such that input impedance Zin_2 of the feed-in network 226 matches with the radiating element RAD_2 and mismatches with the radiating element RAD_1
506
End

FIG. 5

WIRELESS COMMUNICATION DEVICE AND FEED-IN METHOD THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a wireless communication device and feed-in method thereof, and more particularly, to a wireless communication device and feed-in method thereof for dual band transmission and reception.

2. Description of the Prior Art

Electronic products with wireless functions, such as wireless access points (APs) and laptops, transmit and receive radio-frequency (RF) signals through antennas to exchange wireless signals and access wireless network. Therefore, for facilitating users to access wireless network more easily, an ideal antenna should cover more frequency bands and size of the antenna should be reduced to meet a trend of light weight and small size of the electronic products.

A slot antenna is widely used in a conventional wireless device, and has a slot for resonating a single frequency band. However, if a wireless device requires operations of dual frequency bands, e.g. to conform to the IEEE 802.11a/b/g standards at the same time, it takes two single slot antennas to meet such a requirement, which increases antenna area and thus increases size of the wireless device. Moreover, if microstrip lines of the two single slot antennas are connected together to form a single feed-in point, the two single slot antennas influence each other, resulting in frequency shift phenomenon on both of the slot antennas. As a result, a signal diplexer is needed for solving frequency shift phenomenon. Furthermore, a conventional signal diplexer is formed by capacitors and inductances, which also increases the production cost.

As known from the above, there is a need to improve the conventional slot antenna to achieve a dual-band slot antenna to meet a trend of small size and low cost of the wireless electronic products.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a wireless communication device and feed-in method for dual band transmission and reception.

The present invention discloses a wireless communication device including a slot antenna which includes a first feed-in terminal and a second feed-in terminal, a radio-frequency (RF) signal processing module for processing an RF signal transmitted or received by the slot antenna, and an RF signal diplexer coupled between the slot antenna and the RF signal processing module for splitting up the RF signal into a first frequency component and a second frequency component during transmission, and synthesizing the RF signal corresponding to the first frequency component and the second frequency component during reception, the RF signal diplexer includes a first feed-in network coupled between the first feed-in terminal of the slot antenna and the RF signal processing module for transmitting the first frequency component of the RF signal and attenuating the second frequency component of the RF signal, and a second feed-in network coupled between the second feed-in terminal of the slot antenna and the RF signal processing module for attenuating the RF signal corresponding to a first frequency component and transmitting the RF signal corresponding to a second frequency component.

The present invention further discloses a feed-in method for a slot antenna including a first radiating element corresponding to a first frequency component of a radio-frequency signal and a second radiating element corresponding to a second frequency component of the RF signal, the feed-in method includes adjusting a first feed-in network such that a first input impedance of the first feed-in network matches with the first radiating element and mismatches with the second radiating element, and adjusting a second feed-in network such that a second input impedance of the second feed-in network matches with the second radiating element and mismatches with the first radiating element.

These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a wireless communication device according to an embodiment of the present invention.

FIG. **2** is a schematic diagram of the RF diplexer shown in FIG. **1** according to an embodiment of the present invention.

FIG. **3** is a schematic diagram of the feed-in network shown in FIG. **2** according to another embodiment of the present invention.

FIG. **4**A to **4**C are schematic diagrams of top view, bottom view and perspective of the slot antenna shown in FIG. **1**, respectively.

FIG. **5** is a feed-in method according to another embodiment of the present invention.

DETAILED DESCRIPTION

Please refer to FIG. **1**, which is a schematic diagram of a wireless communication device **10** according to an embodiment of the present invention. The wireless communication device **10** can be a wireless access point (AP) as a medium between a local area network (LAN) and other wireless devices, such as laptops and mobile phones etc. The wireless communication device **10** includes a slot antenna **102**, a radio-frequency (RF) signal processing module **104**, and an RF diplexer **106**. The slot antenna **102** is utilized for dual-band operation, and includes feed-in terminals F**1** and F**2** for receiving and transmitting an RF signal RFS, which may comply with IEEE 802.11a/b/g wireless modulation standards, for example. The RF signal processing module **104** is used for processing the RF signal RFS transmitted or received by the slot antenna **102**. The RF diplexer **106** is coupled between the slot antenna **102** and the RF signal processing module **104**, for splitting up the RF signal RFS into frequency components RFS_**1** and RFS_**2** during transmission, and synthesizing the frequency components RFS_**1** and RFS_**2** into the RF signal RFS during reception. In such a situation, the wireless communication device **10** can perform dual-band transmission and reception with the single one slot antenna **102**.

More specifically, when the RF signal processing module **104** transmits the RF signal RFS, the RF signal RFS is split into the frequency component RFS_**1**, e.g. 5.45 GHz, and the frequency component RFS_**2**, e.g. 2.45 GHz, through the RF diplexer **106**. Then, the RF diplexer **106** transmits the frequency components RFS_**1** and RFS_**2** to the feed-in terminals F**1** and F**2** respectively, and the slot antenna **102** radiates the frequency components RFS_**1** and RFS_**2** to the air. On the other hand, when receiving the frequency component RFS_**1** and RFS_**2** of the RF signal RFS, the RF diplexer **106** synthesizes the frequency component RFS_**1** and RFS_**2** into the RF signal RFS, and the RF signal processing module **104** accordingly performs related signal processing on the RF signal RFS, such as demodulation and decoding, etc. As can be seen, the wireless communication device **10** performs dual-band transmission and reception with the single slot antenna **102**; thus, antenna area and production cost can be saved.

Note that, FIG. **1** is to illustrate the concept of the present invention, and those skilled in the art can make modifications according to different system requirements. For example, if the frequency of the frequency component RFS_**1** is substantially twice the frequency of the frequency component RFS_**2**, e.g. 802.11a versus 802.11b, the RF diplexer **106** as well as the slot antenna **102** can be designed as shown in FIG. **2**. In FIG. **2**, the slot antenna **102** is composed of radiating elements RAD_**1** and RAD_**2** for radiating the frequency components RFS_**1** and RFS_**2** of the RF signal RFS, respectively. The RF diplexer **106** includes feed-in networks **216** and **226** between the feed-in terminal F**1** and the RF signal processing module **104** and between the feed-in terminal F**2** and the RF signal processing module **104**, respectively. The feed-in network **216** determines an input impedance Zin_**1** from the RF signal processing module **104** to the radiating element RAD_**1**, and the feed-in network **226** determines an input impedance Zin_**2** from the RF signal processing module **104** to the radiating element RAD_**2**.

The feed-in network **216** includes a transmission line TML_**1** coupled between the feed-in terminal F**1** and the RF signal processing module **104**, and a length L**1** of the transmission line TML_**1** equals a quarter wavelength of the frequency component RFS_**2**. Thus, the feed-in network **216** can transmit the frequency components RFS_**1**, i.e. 5.45 GHz, and attenuate the frequency component RFS_**2**, i.e. 2.45 GHz.

The feed-in network **226** includes a transmission line TML_**2** and an open stub OSB. The transmission line TML_**2** is coupled between the feed-in terminal F**2** and the RF signal processing module **104**, and a length L**2** of the transmission line TML_**2** equals a quarter wavelength of the frequency component RFS_**1**. The open stub OSB is shunted between transmission line TML_**2** and the feed-in terminal F**2** of the slot antenna **102**, and a stub length Ls of the open stub OSB equals the quarter wavelength of the frequency component and RFS_**1**. In such a situation, the transmission line TML_**2** can transmit the frequency components RFS_**2**, and the open stub OSB can filter out the frequency component RFS_**1**.

More specifically, a quarter wavelength of 2.45 GHz signal is substantially equal to a half wavelength of 5.45 GHz signal. Thus, according to the transmission-line theorem, a transmission line with a length equal to the quarter wavelength of 2.45 GHz signal appears to be an open circuit to the 2.45 GHz signal and to be a short circuit to the 5.45 GHz signal, such that the transmission line can attenuate the 2.45 GHz signal and transmit the 5.45 GHz. In such a situation, since the length L**1** of the transmission line TML_**1** equals a quarter wavelength of the frequency component RFS_**2**, i.e. 2.45 GHz, the input impedance Zin_**1** determined by the feed-in network **216** matches with the radiating element RAD_**1**, and mismatches with the frequency component RFS_**2**. Similarly, since the length L**2** of the transmission line TML_**2** equals a quarter wavelength of the frequency component RFS_**1**, and the stub length Ls of the open stub OSB equals a quarter wavelength of the frequency component and RFS_**1**, the input impedance Zin_**2** determined by the network **226** matches with the radiating element RAD_**2**, and mismatches with the frequency component RFS_**1**. Therefore, the feed-in network **216** transmits the frequency component RFS_**1** and attenuates the frequency component RFS_**2**; oppositely, the feed-in network **226** transmits the frequency component RFS_**2** and attenuates the frequency component RFS_**1**.

In addition, the operating frequency of the radiating element RAD_**1** or RAD_**2** is determined by the current route in the radiating element RAD_**1** or RAD_**2**, and a lower operating frequency requires a longer current route. Thus, the length or size of the radiating element RAD_**1** or RAD_**2** can affect the operating frequency. In such a situation, the length L**2** of the transmission line TML_**2** may not be long enough if a distance from the feed-in terminal F**2** to the RF signal processing module **104** is substantially a half wavelength of the frequency component RFS_**1**. For example, if there is substantially a half wavelength of 2.45 GHz between the feed-in terminal F**2** and the RF signal processing module **104**, a transmission line with a length equal to a quarter wavelength of 5.45 GHz is too short to reach the distance. As a result, please further refer to FIG. **3**, which is a schematic diagram of a feed-in network **326** according to an embodiment of the present invention. The feed-in network **326** is utilized for replacing the feed-in network **226** shown in FIG. **2**, and has a structure similar to that of the feed-in network **226**. Compared to the feed-in network **226**, the feed-in network **326** further includes an extending transmission line TML_e cascaded between the transmission line TML_**2** and the feed-in terminal F**2**. A length Le of the extending transmission line TML_e is substantially a quarter wavelength of the frequency component RFS_**2**, in order to compensating a distance from the feed-in terminal F**2** to the transmission line TML_**2** and keep the input impedance Zin_**2** match with the radiating element RAD_**2**.

Noticeably, the present invention adjusts the feed-in networks **216** and **226** of the RF diplexer **106**, to split up or synthesize the RF signal RFS. Those skilled in the art should make modifications or alterations according to different requirements. For example, methods of adjusting the feed-in networks **216** and **226** are not limited, e.g. combinations of cascading transmission lines and shunting stubs, lengths of transmission line and open stub, and positions of shunted open stubs are not limited, as long as the input impedance Zin_**1** matches with the radiating element RAD_**1** and mismatches with the radiating element RAD_**2**, and the input impedance Zin_**2** matches with the radiating element RAD_**2** and mismatches with the radiating element RAD_**1**. As a result, the slot antenna **102** can operate in dual band through the feed-in networks **216** and **226** of the RF diplexer **106** without two conventional single band slot antennas, and thus save antenna size and cost of the wireless communication device **10**.

In addition, implementation of the slot antenna **102** is not limited in any rule as long as the slot antenna **102** can accurately receive or transmit the RF signal RFS. For example, FIG. **4**A to **4**C are schematic diagrams of top view, bottom view and perspective of an embodiment of the slot antenna **102**. As shown in FIG. **4**A to **4**C, the slot antenna **102** includes a substrate **402**, feeding microstrip lines **412** and **422**, radiating elements **414** and **424**, and a connection element **404**. The feeding microstrip lines **412** and **422** are formed on a bottom layer of the substrate **402** along a direction Y for transmitting the frequency components RFS_**1** and RFS_**2**, respectively. The radiating elements **414** and **424** are formed on a top layer of the substrate **402** for radiating the frequency components RFS_**1** and RFS_**2**, respectively. The radiating elements **414** and **424** further include slots **416** and **426** formed along a direction X. The connection element **404** is formed on the top layer of the substrate **402** for connecting the radiating elements **414** and **424**. Furthermore, the feed-in networks **216** and **226** of the RF diplexer **106** are formed on the bottom layer of the substrate **402**. As shown in FIG. **4**A, the slot antenna **102** is formed by cutting two conventional single slot antennas by half, which becomes the radiating elements **414** and **424**. As shown in FIG. **4**C, the slot antenna **102** and RF diplexer **106** both are printed on the top layer and bottom layer of the substrate **402**, respectively, which has advantages such as saving area and easy for manufacture. Besides, a conventional diplexer is formed by capacitors and inductances; on the contrary, the present invention realizes the RF diplexer **106** by printed circuit, so as to save cost of the wireless communication device **10**.

Operations of the wireless communication device **10** can be summarized into a feed-in method **50** as shown in FIG. **5**. The feed-in method **50** includes the following steps:

Step **500**: Start.

Step **502**: Adjust the feed-in network **216** such that input impedance Zin_**1** of the feed-in network **216** matches with the radiating element RAD_**1** and mismatches with the radiating element RAD_**2**.

Step **504**: Adjust the feed-in network **226** such that input impedance Zin_**2** of the feed-in network **226** matches with the radiating element RAD_**2** and mismatches with the radiating element RAD_**1**.

Step **506**: End.

Details of the feed-in method **50** can be derived by referring to the above description.

To sum up, the conventional slot antenna only operates with single frequency band, takes two single slot antennas to achieve dual frequency bands, and thus increases antenna area and cost. The present invention realizes the dual band slot antenna by combining two single band slot antennas and the RF diplexer with a double layer printed circuit board, so as to reduce antenna area and save production cost.

Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention.

What is claimed is:

1. A wireless communication device, comprising:

a slot antenna, comprising a first feed-in terminal and a second feed-in terminal, wherein the first feed-in terminal is different from the second feed-in terminal;

a radio-frequency (RF) signal processing module, for processing an RF signal transmitted or received by the slot antenna; and

an RF signal diplexer, coupled between the slot antenna and the RF signal processing module, for splitting up the RF signal into a first frequency component and a second frequency component during transmission, and synthesizing the first frequency component and the second frequency component into the RF signal during reception, the RF signal diplexer comprising:

a first feed-in network, coupled between the first feed-in terminal of the slot antenna and the RF signal processing module, for transmitting the first frequency component of the RF signal and attenuating the second frequency component of the RF signal; and

a second feed-in network, coupled between the second feed-in terminal of the slot antenna and the RF signal processing module, for attenuating the first frequency component of the RF signal and transmitting the second frequency component of the RF signal.

2. The wireless communication device of claim **1**, wherein the first feed-in network comprises:

a first transmission line, coupled to the first feed-in terminal of the slot antenna and the signal processing module, for transmitting the first frequency component of the RF signal and attenuating the second frequency component of the RF signal;

wherein a length of the first transmission line is equal to or greater than a quarter wavelength of the second frequency component.

3. The wireless communication device of claim **1**, wherein the second feed-in network comprises:

a second transmission line, coupled to the second feed-in terminal of the slot antenna and the signal processing module, for transmitting the second frequency component of the RF signal and attenuating the first frequency component of the RF signal; and

an open stub, shunted between the first transmission line and the slot antenna, for attenuating the first frequency component of the RF signal;

wherein a length of the first transmission line and a length of the open stub are equal to a quarter wavelength of the first frequency component.

4. The wireless communication device of claim **3**, wherein the first feed-in network further comprises:

an extending transmission line, cascaded between the open stub and the slot antenna, for extending the second transmission line, to compensate a distance from the second feed-in terminal of the slot antenna to the second feed-in network;

wherein a length of the extending transmission line is substantially equal to the quarter wavelength of the second frequency component.

5. The wireless communication device of claim **1**, wherein a first frequency of the second frequency component is substantially twice a frequency of the first frequency component.

6. The wireless communication device of claim **1**, wherein the slot antenna further comprises:

a substrate;

a first radiating element, formed on a first layer of the substrate, for transmitting and receiving the first frequency component of the RF signal;

a second radiating element, formed on the first layer of the substrate, for transmitting and receiving the second frequency component of the RF signal;

a connecting bridge, coupled between the first radiating element and the second radiating element, for connecting the first radiating element and the second radiating element;

a first feeding microstrip line, formed on a second layer of the substrate, for transmitting and receiving the first frequency component of the RF signal; and

a second feeding microstrip line, formed on a second layer of the substrate, for transmitting and receiving the second frequency component of the RF signal.

7. The wireless communication device of claim **6**, wherein the first radiating element and the second radiating element respectively comprise a first slot and a second slot formed along a first direction.

8. The wireless communication device of claim **7**, wherein the first feeding microstrip line and the second feeding microstrip line are formed along a second direction perpendicular to the first direction.

9. A feed-in method for a slot antenna comprising a first radiating element corresponding to a first frequency component of a radio-frequency (RF) signal and a second radiating element corresponding to a second frequency component of the RF signal, the feed-in method comprising:

adjusting a first feed-in network such that a first input impedance of the first feed-in network matches with the first radiating element and mismatches with the second radiating element, wherein the first input impedance of the first feed-in network mismatching with the second radiating element attenuates the second frequency component of the RF signal, and wherein the first radiating element is different from the second radiating element; and

adjusting a second feed-in network such that a second input impedance of the second feed-in network matches with the second radiating element and mismatches with the first radiating element, wherein the second input impedance of the second feed-in network mismatching with the first radiating element attenuates the first frequency component of the RF signal.

10. The feed-in method of claim **9**, wherein the step of adjusting the first feed-in network comprises:

cascading a transmission line to the slot antenna, for transmitting the first frequency component of the RF signal and attenuating the second frequency component of the RF signal.

11. The feed-in method of claim **9**, wherein the step of adjusting the second feed-in network comprises:

cascading a transmission line to the slot antenna, for transmitting the second frequency component of the RF signal; and

shunting an open stub between the transmission line and the slot antenna, for filtering out the first frequency component of the RF signal.

12. The feed-in method of claim **11**, wherein the step of adjusting the second feed-in network further comprises:

cascading an extending transmission line between the transmission line and the slot antenna, for compensating a distance from the second feed-in network to the slot antenna.

* * * * *